CLAIMS:

1. A resonator cavity comprising at least one gain medium and end reflectors which define together longitudinal modes of light in the cavity, the cavity further comprising an intra-cavity beam coupler assembly configured to split light impinging thereon into a predetermined number of spatially separated light channels, and to cause phase locking and at least partial coherent combining of the light channels, which have common longitudinal and transverse modes, in a double pass through the beam coupler assembly, the resonator cavity being configured and operable to produce at least one output combined light channel of a predetermined intensity profile.

2. The resonator cavity of Claim 1, wherein the light channels are associated with the single gain medium.

3. The resonator cavity of Claim 1, wherein the beam coupler assembly is configured as an interferometric coupler assembly.

4. The resonator cavity of Claim 3, wherein the interferometric coupler assembly comprises a plane parallel plate, each of front and rear facets of the plate having a predetermined pattern formed by regions of predetermined transmission or reflectivity, said plane parallel plate having a predetermined thickness d and being oriented with respect to a light propagation cavity axis at a predetermined angle defining a certain angle α of light incidence onto the plate so as to ensure said splitting and said at least partial coherent combining of the light channels in the double pass through the plate.

5. The resonator cavity of Claim 4, wherein for the incident angle α, the thickness d of the plate is determined as:

$$d = x_0 / \{ 2 \cos\alpha \; tg[\arcsin(\sin\alpha / n)] \}$$

wherein x_0 is a distance between propagation axes of the light channels, and n is a refractive index of a material of the plate, thereby providing for matching the distance between the light channels so as to enable an optimal overlap between the light channels and their parallel propagation after exiting the beam coupler assembly.

6. The resonator cavity of Claim 3, wherein the beam coupling assembly is configured to provide for phase locking and partial coherent combining of the light, the output being in the form of a single large mode intensity profile with a well defined phase.

5   7. The resonator cavity of Claim 5, wherein each of the front and rear facets of the plate has the predetermined pattern formed by regions of predetermined uniform transmission or reflectivity.

8. The resonator cavity of Claim 7, wherein the front facet includes a substantially transmitting region and a region of the predetermined partially light 10 transmitting property, and the rear facet includes a region of said predetermined partially light transmitting property and a substantially transmitting region, the dimensions of the regions on the front and rear facets and the orientation of the plane parallel plate being such as to allow light passage through the plate to the partially transmitting region on the rear facet, where light is reflected from said 15 partially transmitting region of the rear facet towards the partially transmitting region of the front facet, which reflects light to the transmitting region on the rear facet.

9. The resonator cavity of Claim 8, wherein the output end reflector is accommodated in an optical path of light emerging from the rear facet.

20   10. The resonator cavity of Claim 7, wherein said beam coupler assembly comprises gratings.

11. The resonator cavity of Claim 10, wherein the beam coupler assembly comprises a plane parallel plate with front and rear facets of the plate carrying first and second gratings, respectively, the first grating splitting the light into various 25 diffraction orders, which propagate inside the plate towards the second grating.

12. The resonator cavity of Claim 11, wherein a thickness of the plate, and the gratings pattern are selected such that the light constructively and destructively interfere at the second grating, thus providing for spatial coupling the within the light beam.

13. The resonator cavity of Claim 12, wherein the gratings are configured such that most of the light energy is distributed between 0, +1, -1 orders, with substantially low energy in higher diffraction orders.

14. The resonator cavity of Claim 1, comprising an intra-cavity aperture arrangement configured to select, in at least one light channel, a predetermined transverse mode content corresponding to said predetermined intensity profile.

15. The resonator cavity of Claim 14, wherein the aperture arrangement has one of the following configurations: (a) comprises multiple apertures each associated with the respective one of said light channels propagating between the rear end reflector and the beam coupler assembly; (b) comprises a single aperture associated either with one of the light channels propagating between the rear end reflector and the beam coupler assembly or with one combined channel propagating between the beam coupler assembly and the output end reflector; and (c) comprises a large aperture associated with all the light channels propagating between the rear end reflector and the beam coupler assembly.

16. The resonator cavity of Claim 14, comprising a lenslet array configured and oriented such that each lens of the lenslet array is associated with a corresponding one of the light channels.

17. The resonator cavity of Claim 14, wherein the beam coupling assembly is configured to provide coherent combining of the light channels to produce the single output combined channel.

18. The resonator cavity of Claim 14, wherein the beam coupling assembly is configured to provide the partial coherent combining of the light channels to produce the multiple spatially separated output combined light channels, which are phase locked.

19. The resonator cavity of Claim 17, wherein the beam coupler assembly includes at least one simple beam splitter/combiner.

20. The resonator cavity of Claim 17, comprising N gain media producing N light channels, respectively, said beam coupler assembly including $(N-1)$ simple beam splitter/combiners.

21. The resonator cavity of Claim 14, wherein the beam coupler assembly is configured as an interferometric coupler assembly.

22. The resonator cavity of Claim 21, wherein the interferometric coupler assembly comprises a plane parallel plate, each of front and rear facets of the plate having a predetermined pattern formed by regions of predetermined transmission or reflectivity, the plane parallel plate having a predetermined thickness d and being oriented with respect to a light propagation cavity axis at a predetermined angle defining a certain angle α of light incidence onto the plate so as to ensure said splitting and said at least partial coherent combining of the light channels in the double pass through the plate.

23. The resonator cavity of Claim 22, wherein for the incident angle α, the thickness d of the plate is determined as:

$$d = x_0 / \{ 2 \cos\alpha \; tg[\arcsin(\sin\alpha / n)] \}$$

wherein x_0 is a distance between propagation axes of the light channels, and n is a refractive index of a material of the plate, thereby providing for matching the distance between the light channels so as to enable an optimal overlap between the light channels and their collinear propagation after exiting the beam coupler assembly.

24. The resonator cavity of Claim 21, wherein the front facet includes a substantially light transmitting region, and a region formed by $(N-1)$ different beam splitting sub-regions for N light channels, respectively, each i-th beam splitting sub-region, i=2,...N, having a reflectivity of $(1-1/i)$ or transmittance of $1/i$, such that the first light channel is substantially not affected by the front facet and the other $(N-1)$ light channels are differently affected by said $(N-1)$ beam splitting regions, respectively; and the rear facet includes a relatively large highly reflective region and a substantially light transmitting region, the dimensions of the regions on the front and rear facets and the orientation of the plane parallel plate being such as to allow light passage through the front facet to the highly reflective region of the rear facet where light is reflected towards the beam splitting region in the front surface where it is partly reflected back to the highly reflective region on the rear facet.

25. The resonator cavity of Claim 24, wherein the output end reflector is accommodated in an optical path of light emerging from the rear facet.

26. The resonator cavity of Claim 24, wherein the beam coupling assembly is configured to provide full coherent combining of the light channels to produce the single output combined channel, the output end reflector being accommodated in an optical path of light coming from the front facet.

27. The resonator cavity of Claim 21, wherein

the output end reflector is accommodated in an optical path of a light portion that is reflected from the front facet;

the front facet includes a region formed by $(N-1)$ different beam splitting sub-regions for N light channels, respectively, each i-th beam splitting sub-region, i=2,...N, having a reflectivity of $(1-1/i)$ or transmittance of $1/i$, said region of (N-1) sub-regions being surrounded by substantially light transmitting regions, such that the first light channel is substantially not affected by the front facet and the other $(N-1)$ light channels are differently affected by said $(N-1)$ beam splitting regions, respectively; and the rear facet is highly reflective, the dimensions of the regions on the front facets and the orientation of the plane parallel plate being such as to allow light passage through the front facet to the highly reflective rear facet where light is reflected towards the beam splitting sub-region in the front surface where it is partly reflected back to the highly reflective rear facet which reflects light to pass through the substantially light transmitting region on the front facet towards the output end reflector.

28. The resonator cavity of Claim 21, wherein the substantially transmitting regions are formed by an anti-reflecting coating on the plate.

29. The resonator cavity of Claim 21, wherein the beam coupler assembly is oriented at a Brewster angle with respect to the cavity axis, and the input light has specific linear polarization.

30. The resonator cavity of Claim 21, wherein the front facet of the plane parallel plate comprises the single beam splitting sub-region, thereby producing two light channels.

31. The resonator cavity of Claim 18, wherein the beam coupler assembly is configured as an interferometric coupler assembly.

32. The resonator cavity of Claim 31, wherein the phase locking interferometric coupler assembly comprises a plane parallel plate, each of front and rear facets of
5   the plate having a predetermined pattern formed by regions of predetermined transmission or reflectivity, the plane parallel plate having a predetermined thickness d and being oriented with respect to a light propagation cavity axis at a predetermined angle defining a certain angle α of light incidence onto the plate so as to ensure said splitting and said at least partial coherent combining of the light
10   channels in the double pass through the plate.

33. The resonator cavity of Claim 32, wherein for the incident angle α, the thickness d of the plate is determined as:

$$d = x_o / \{ 2 \cos\alpha \; tg[\arcsin(\sin\alpha / n)] \}$$

wherein x_0 is a distance between propagation axes of the light channels, and n is a
15   refractive index of a material of the plate, thereby providing for matching the distance between the light channels so as to enable an optimal overlap between the light channels and their parallel propagation after exiting the beam coupler assembly.

34. The resonator cavity of Claim 32, wherein the front facet includes a
20   substantially transmitting region and a region formed by $(N-1)$ partially transmitting sub-regions for N light channels, respectively, such that the first light channel is substantially not affected by the front facet and the other $(N-1)$ light channels are differently affected by said $(N-1)$ partially transmitting sub-regions, respectively; and the rear facet includes a substantially transmitting region aligned with the
25   partially transmitting region of the front facet, and a region of at least one sub-region of a predetermined partially light transmitting property, the dimensions of the regions on the front and rear facets and the orientation of the plane parallel plate being such as to allow light passage through the plate to the partially transmitting region on the rear facet, where light is reflected from said partially transmitting
30   region of the rear facet towards the partially transmitting region of the front facet.

35. The resonator cavity of Claim 34, wherein the output end reflector is accommodated in an optical path of light emerging from the rear facet.

36. The resonator cavity of Claim 32, wherein the substantially transmitting region is formed by an anti-reflecting coating on the respective region of the plate.

37. The resonator cavity of Claim 32, wherein the beam coupler assembly is oriented at a Brewster angle with respect to the cavity axis, and the input light has specific linear polarization.

38. The resonator cavity of Claim 31, comprising a lenslet array configured and oriented such that each lens of the lenslet array is associated with a corresponding one of the light channels.

39. The resonator cavity of Claim 31, wherein the output end reflector is configured to define an array of concave output reflectors.

40. The resonator cavity of Claim 18, wherein said beam coupler assembly comprises gratings.

41. The resonator cavity of Claim 40, wherein the aperture arrangement comprises multiple apertures for defining said light channels, respectively, each aperture being configured to define the required transverse mode, the device providing the output in the form of definite multiple beams with the locked phase.

42. The resonator cavity of Claim 40, wherein the aperture arrangement comprises a single large aperture, the device providing the output in the form of a single large coherent distribution with well defined amplitude and phase distribution.

43. The resonator cavity of Claim 41, wherein the beam coupler assembly comprises a plane parallel plate with front and rear facets of the plate carrying first and second gratings, respectively, the first grating split the light into various diffraction orders, which propagate inside the plate towards the second grating.

44. The resonator cavity of Claim 43, wherein the aperture spacing, a thickness of the plate, and the gratings pattern are selected such that the light of the neighboring channels constructively and destructively interfere at the second grating, thus coupling the channels.

45. The resonator cavity of Claim 44, wherein the gratings are configured such that most of the light energy is distributed between 0, +1, -1 orders, with substantially low energy in higher diffraction orders.

46. The resonator cavity of Claim 42, wherein the beam coupler assembly comprises a plane parallel plate with front and rear facets of the plate carrying first and second gratings, respectively, the first grating split the. light into various diffraction orders, which propagate inside the plate towards the second grating.

47. The resonator cavity of Claim 46, wherein the aperture spacing, a thickness of the plate, and the gratings pattern are selected such that the light constructively and destructively interfere at the second grating, thus providing for spatial coupling the within the beam.

48. The resonator cavity of Claim 47, wherein the gratings are configured such that most of the light energy is distributed between 0, +1, -1 orders, with substantially low energy in higher diffraction orders.

49. The resonator cavity of Claim 21, wherein the interferometric coupler assembly comprises a pair of first interferometric coupler elements associated with a pair of the gain media, respectively, and operating to produce two combined light components, respectively; and a second interferometric coupler element for combining said two combined light components, to produce the single output coherently combined channel.

50. The resonator cavity of Claim 49, wherein each of the interferometric coupler elements is a plane parallel plate, each of front and rear facets of the plate having a predetermined pattern formed by regions of predetermined transmission or reflectivities, the plane parallel plate having a predetermined thickness d and being oriented with respect to a light propagation axis at a predetermined angle defining a certain angle α of light incidence onto the plate so as to ensure said splitting and said at least partial coherent combining of the light channels in the double pass through the plate.

51. The resonator cavity of Claim 50, wherein for the incident angle α, the thickness d of the plate is determined as:

$$d = x_0 / \{ 2 \cos\alpha \ tg[\arcsin(\sin\alpha / n)] \}$$

wherein x_0 is a distance between propagation axes of the light channels, and n is a refractive index of a material of the plate, thereby providing for matching the distance between the light channels so as to enable an optimal overlap between the light channels and their collinear propagation after exiting the beam coupler

5   assembly.

52. The resonator cavity of Claim 50, wherein the front facet includes a substantially transmitting region and at least one region of a predetermined beam splitting property; and the rear facet includes a substantially transmitting region aligned with the beam splitting region of the front facet, and a highly reflective

10   region; the dimensions of said regions and the orientation of the plane parallel plate being such as to allow light passage through the plate to the highly reflective region, where light is reflected from the highly reflective region towards the beam splitting region, reflected back towards the high reflective region, and so on.

53. The resonator cavity of claim 52, wherein the output end reflector is

15   accommodated in an optical path of light emerging from the rear facet of the second interferometric coupler.

54. The resonator cavity of Claim 50, wherein the substantially transmitting region of the facet is formed by an anti-reflecting coating on the facet.

55. The resonator cavity of Claim 50, wherein the beam coupler assembly is

20   oriented at a Brewster angle with respect to the cavity axis, and the input light has specific linear polarization.

56. The resonator cavity of Claim 14, wherein the beam coupler assembly is a polarization coupler assembly.

57. The resonator cavity of Claim 56, wherein the polarization coupler

25   assembly comprises two polarizers accommodated in a spaced-apart relationship along an axis of the cavity; and an optical element configured as a $\lambda/2$ retardation plate or 45° polarization rotator accommodated between the two polarizers.

58. The resonator cavity of Claim 15(b), wherein said single aperture has a diameter capable of carrying out one of the following: (i) selecting the lowest

30   transverse TEM_{00} mode distribution, thereby enabling to impose this mode of said one light channel on one or more other light channels and the coherent combining

of all the light channels by the beam coupler assembly; (ii) selecting a desired multiple-transverse-mode distribution, thereby enabling to impose the desired multiple-transverse-mode distribution of said one light channel on one or more other light channels and the coherent combining of all the light channels by the

5   beam coupler assembly; and (iii) selecting a desired single high-order transverse mode distribution, thereby enabling to impose the single high-order transverse-mode distribution of said one light channel on one or more other light channels and the coherent combining of all the light channels by the beam coupler assembly, the cavity further comprising a phase element.

10   59. The resonator cavity of Claim 58, wherein said one light channel is the output combined light channel.

60. The resonator cavity of Claim 15(a), wherein each of the apertures has a diameter capable of carrying out at least one of the following: (i) selecting the lowest transverse TEM_{00} mode distribution; (ii) selecting a desired multiple-

15   transverse-mode distribution; and (iii) selecting a desired single high-order transverse mode distribution.

61. The resonator cavity of Claim 60, comprising a phase element.

62. The resonator cavity of Claim 14, wherein the beam coupler assembly comprises first and second interferometric beam coupler elements accommodated

20   between the gain medium and the output end reflector in a spaced apart relation along the light propagation cavity axis, the first and second interferometric coupler elements being configured and operable to produce first and second pairs, respectively, of parallel light channels, coherently combine the first and second pairs of the light channels into two combined light channels, and combine these two

25   light channels into the single output combined channel.

63. The resonator cavity of Claim 62, wherein the aperture arrangement comprises a single substantially rectangular aperture accommodated upstream of the beam coupler assembly, with respect to a direction of light propagation from the rear end reflector to the output end reflector, so as to be in an optical path of said

30   first and second pairs of the light channels.

64. The resonator cavity of Claim 63, for a given length of the resonator cavity and given curvatures of the end reflectors, a size of the aperture is selected to correspond to that of the four tightly packed channels.

65. The resonator cavity of Claim 62, wherein the aperture arrangement is accommodated upstream of the beam coupler assembly, with respect to a direction of light propagation from the rear end reflector to the output end reflector, the aperture arrangement comprising a first pair of apertures associated with the first pair of channels and arranged in a spaced-apart relationship along an axis perpendicular to the cavity axis, and a second pair of apertures associated with the second pair of the light channels and accommodated in a spaced-apart relationship along an axis parallel to and spaced-apart from the axis of the first apertures arrangement.

66. The resonator cavity of Claim 62, wherein the aperture arrangement comprises a single aperture accommodated between the beam coupler assembly and the output end reflector so as to be in an optical path of the output combined channel.

67. A resonator cavity comprising at least one gain medium and end reflectors which define together longitudinal modes of light in the cavity, the resonator cavity further comprising:

(a) a beam coupler assembly configured to split light impinging thereon into a predetermined number of spatially separated light channels, and to cause phase locking and at least partial coherent combining of the light channels, having common longitudinal and transverse modes, in a double pass through the beam coupler assembly, to thereby produce at least one output combined light channel; and

(b) an aperture arrangement configured to select in at least one of the light channels, a predetermined transverse mode content that is desired at the cavity output.

68. A resonator cavity comprising at least one gain medium and end reflectors which define together longitudinal modes of light in the cavity, the resonator cavity further comprising:

a beam coupler assembly configured to split light impinging thereon into a predetermined number of spatially separated light channels, and to cause phase locking and coherent combining of the light channels, having common longitudinal and transverse modes, in a double pass through the beam coupler assembly, to thereby produce an output combined light channel, the beam coupler assembly being configured for polarization coupling of the light channels and comprising two polarizers accommodated in a spaced-apart relationship along an axis of the cavity; and an optical element configured as a $\lambda/2$ retardation plate or 45° polarization rotator accommodated between the two polarizers; and

an aperture arrangement configured to select in at least one of the light channels a predetermined transverse mode content that is desired at the cavity output.

69. A beam coupler element for use in a resonator cavity for controlling light propagating through the resonator cavity to provide an output light channel in the form of coherent addition of at least two light channels having common longitudinal modes, the beam coupler assembly comprising a plane parallel plate with its front and rear facets being patterned to have regions of predetermined transmission or reflectivities, wherein: the front facet includes a substantially transmitting region and (N-1) beam splitting regions for N light channels, respectively, each i-th beam splitting region, i=2,...N, having a reflectivity of (1-1/i) or transmittance of $1/i$, such that the first light channel is substantially not affected by the front facet and the other (N-1) light channels are differently affected by the (N-1) beam splitting regions, respectively; the rear facet includes a highly reflective region; and dimensions of said regions of the front and rear facet and orientation of the plane parallel plate with respect to the light channels' propagation axis are such that light is reflected from the highly reflective region towards the beam splitting region, reflected back from the beam splitting region to the highly reflective region and so on.

70. A beam coupler element for use in a resonator cavity for controlling light propagating through the resonator cavity to provide at least two phase locked output light channels of desired transverse and longitudinal modes, the beam coupler

assembly comprising: a plane parallel plate with its front and rear facets being patterned to have regions of predetermined transmission or reflectivities, wherein: the front facet includes a substantially transmitting region and at least one predetermined beam splitting region; the rear facet includes at least one

5   predetermined beam splitting region; and dimensions of said regions of the front and rear facets and orientation of the plane parallel plate with respect to the light channels' propagation axis are such that light is reflected from the beam splitting region of the rear facet towards the beam splitting region of the front facet and *vice versa*.

10   **71.** A beam coupler element for use in a resonator cavity for controlling light propagating through the resonator cavity to provide at least two output light channels of desired transverse and longitudinal modes, the beam coupler assembly comprising: a plane parallel plate with its front and rear facets carrying first and second gratings, respectively, the first grating splitting the light into various

15   diffraction orders and allowing their propagation inside the plate towards the second grating.

72. A beam coupler element for use in a resonator cavity for controlling light propagating through the resonator cavity to provide an output light channel in the form of coherent addition of at least two light channels having common

20   longitudinal modes, the beam coupler assembly comprising two polarizers accommodated in a spaced-apart relationship along an axis of light propagation through the resonator cavity; and an optical element configured as a $\lambda/2$ retardation plate or 45° polarization rotator accommodated between the two polarizers.